1962-06-01

A layman's guide to automatic data processing in air traffic control.

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George Washington University

A LAYMAN'S GUIDE TO AUTOMATIC DATA PROCESSING IN AIR TRAFFIC CONTROL

EMIDDIO MASSA

A LAYMAN'S GUIDE TO AUTOMATIC DATA PROCESSING IN AIR TRAFFIC CONTROL

by

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BACHELOR OF ARTS
1957
THE GEORGE WASHINGTON UNIVERSITY

A thesis submitted to the faculty of the School of Government, Business and International Affairs of The George Washington University in partial satisfaction of the requirements for the degree of Master of Business Administration.

June 6, 1962

Thesis directed by
Arlin Rex Johnson, Ph.D.,
Professor of Business Administration

PREFACE

"For I dipt into the future, far as human eye could see,
Saw the Vision of the world, and all the wonder that could be;

Saw the heavens fill with commerce, argosies of magic sails
Pilots of the purple twilight, dropping down with costly bales;

Heard the heavens fill with shouting and there rain'd a ghastly dew
From the nations' airy navies grappling in the central blue; "

-- Tennyson, Alfred Lord,
Locksley Hall

Being thoroughly fascinated by the potential uses of automatic data processing systems, the writer investigated the field to find a generalized introduction in layman's language of the uses of ADP in air traffic control. Such use is quite new and installation of new equipments is still in progress. Technical information exists in prolific amounts, but manufacturers and users of ADP have so accelerated sophistication that basic introductory material is not available. The Federal Government relies on specialists to prepare studies relating to problems of air traffic control. There are many executives, and in fact, there are many users of the airways who are not fully aware of the potential uses of ADP in air traffic control. The casual, weekend pleasure pilot, the professional airline captain and the specialized military aviator do not have available a directive or paper in a form satisfactorily to meet their basic requirements. This paper is an effort on the part of the writer to assist in fulfilling this requirement.

I express my appreciation to Messrs. Stewart Dawson, Thomas Grieg, and Stanley Kingman of the Federal Aviation Agency for their time and patience in answering many questions posed by the author in pursuit of additional information.

I am especially grateful to Miss Helen McNulta, Assistant to the Director of The Navy Graduate Financial Management Program, The George Washington University, for her painstaking assistance in the editing of the text, and for the interest and enthusiasm with which she performed her work.

In addition to these acknowledgements of specific assistance, I express my deep appreciation to Dr. A. Rex Johnson, Director of The Navy Graduate Financial Management Program, for the friendly counsel I have received from him and for his infinite patience with my shortcomings.

This paper is dedicated to my wife. Her encouragement and criticisms provided the impetus required to continue.

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CHAPTER I

THE CROWDED SKY

Increasing air traffic activity has created a multiplicity of problems in the control of airborne traffic particularly in terminal areas. Aircraft Traffic Control Centers (ATCC) are being utilized in many areas to maximum effectiveness during periods of inclement weather. Further improvement in the control of air traffic, using present-day methodology will not yield substantial improvement without excessive complexity. It is believed that the point in time where our aviation facilities are capable of safely and efficiently handling <u>all</u> the aircraft desiring to fly has already passed. Our present-day manual system, supplemented, in part, by computer-prepared flight strips, has been just barely able to absorb the growth in civil aircraft population from 29,000 in 1936 to over 98,000[1] in 1961. This ability to handle the tremendous increase in air traffic has been made possible by patchwork improvements and short-term quick fixes. Today's safety level is obtained by imposing arbitrary and costly delays upon civil and military aviation. These restrictions could have serious consequences in times of national stress.

General aviation and air carrier flying are expected to increase almost 80% by 1975, and although military flying is expected to decrease by 30%, the net <u>increase</u> will be an impressive 44% in 1975 over 1960. <u>However</u>, controlled traffic, which represents the load on the air traffic control system, will increase about 300% in the same period. As the numbers of

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[1] FAA <u>Statistical Handbook of Aviation</u>, 1961 Edition, p. 37.

aircraft increase, there will also be an increase in the volume of aircraft movements in terminal areas. See Figure 1 for total aircraft operations for fiscal years 1952 - 1961. While in 1952, there were 16 million take-offs and landings at the Nation's airports controlled by FAA, in 1961 there were over 25 million. Of course these totals do not take into account the millions of aircraft operations conducted at airports without FAA control towers, e.g., private airports. It is conservatively estimated that the total number of aircraft operations, including private aircraft, will reach the staggering figure of 115 million by 1975. Figure 2 illustrates total ARTCC instrument approaches handled for the period 1952-1961. Figure 3 shows the forecast of instrument approaches to year 1970. Figure 4 shows the instrument approaches reported by FAA ARTCC for fiscal years 1953 - 1961. It is interesting to note that military activity declined rapidly after 1958. Figure 5 graphically portrays this decline in total military operations.

TOTAL AIRCRAFT OPERATIONS AT AIRPORTS HAVING FAA TRAFFIC CONTROL SERVICE

FISCAL YEARS 1952-1961

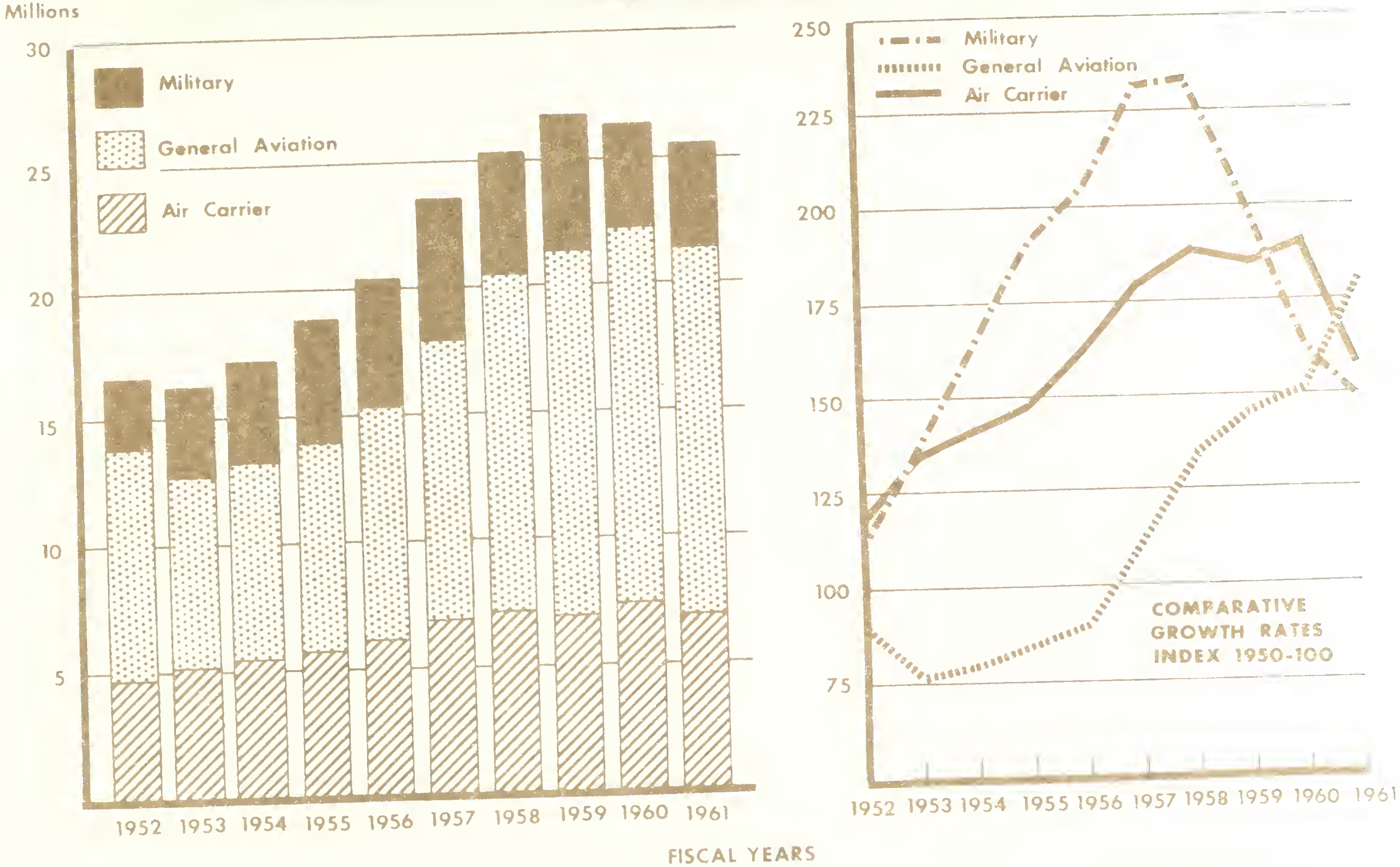
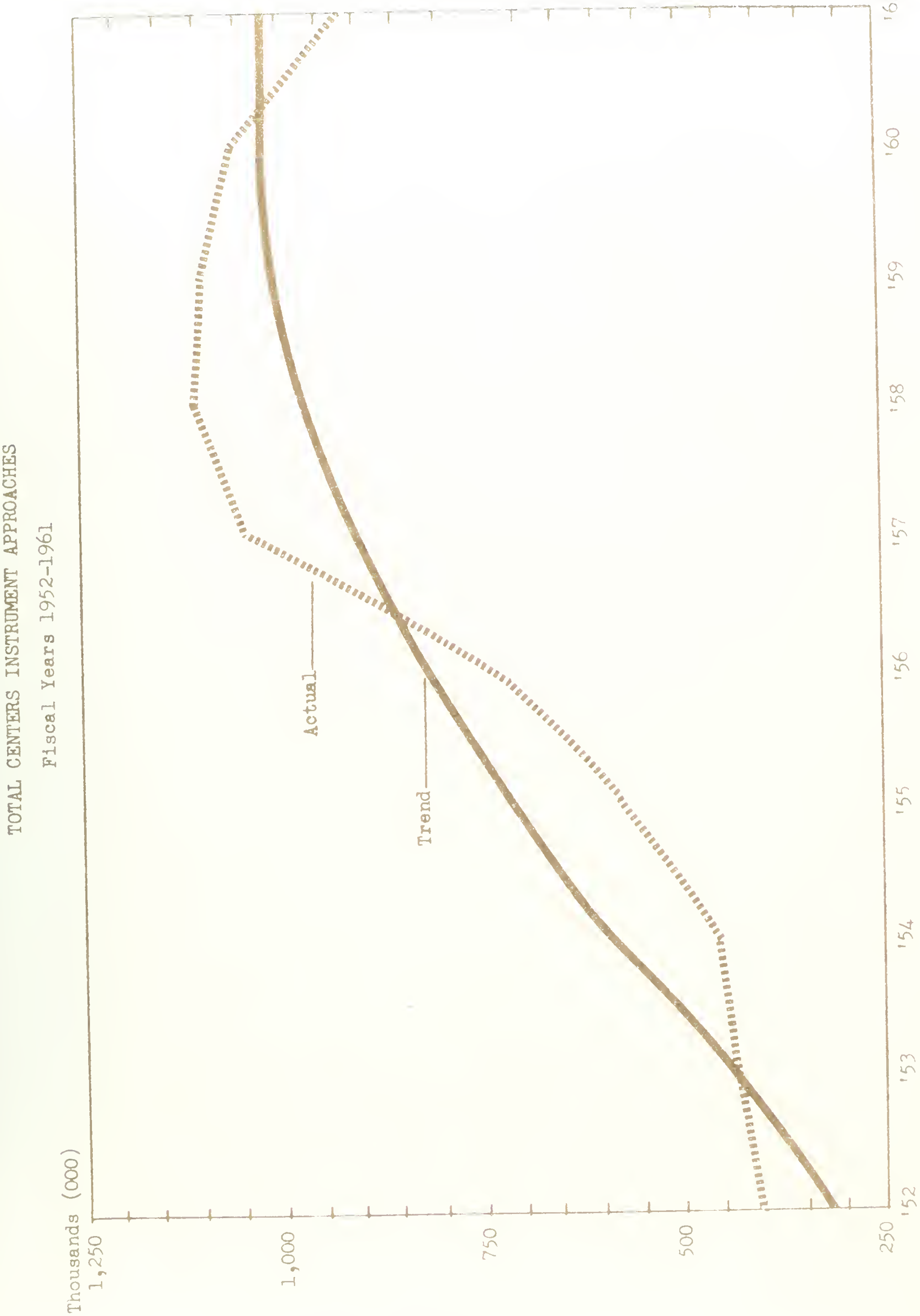


Figure 1



TOTAL CENTERS INSTRUMENT APPROACHES
Fiscal Years 1952-1961
Thousands (000)
1,250
1,000
750
500
250
'52
'53
'54
'55
'56
'57
'58
'59
'60
'61
Actual
Trend

Figure 2

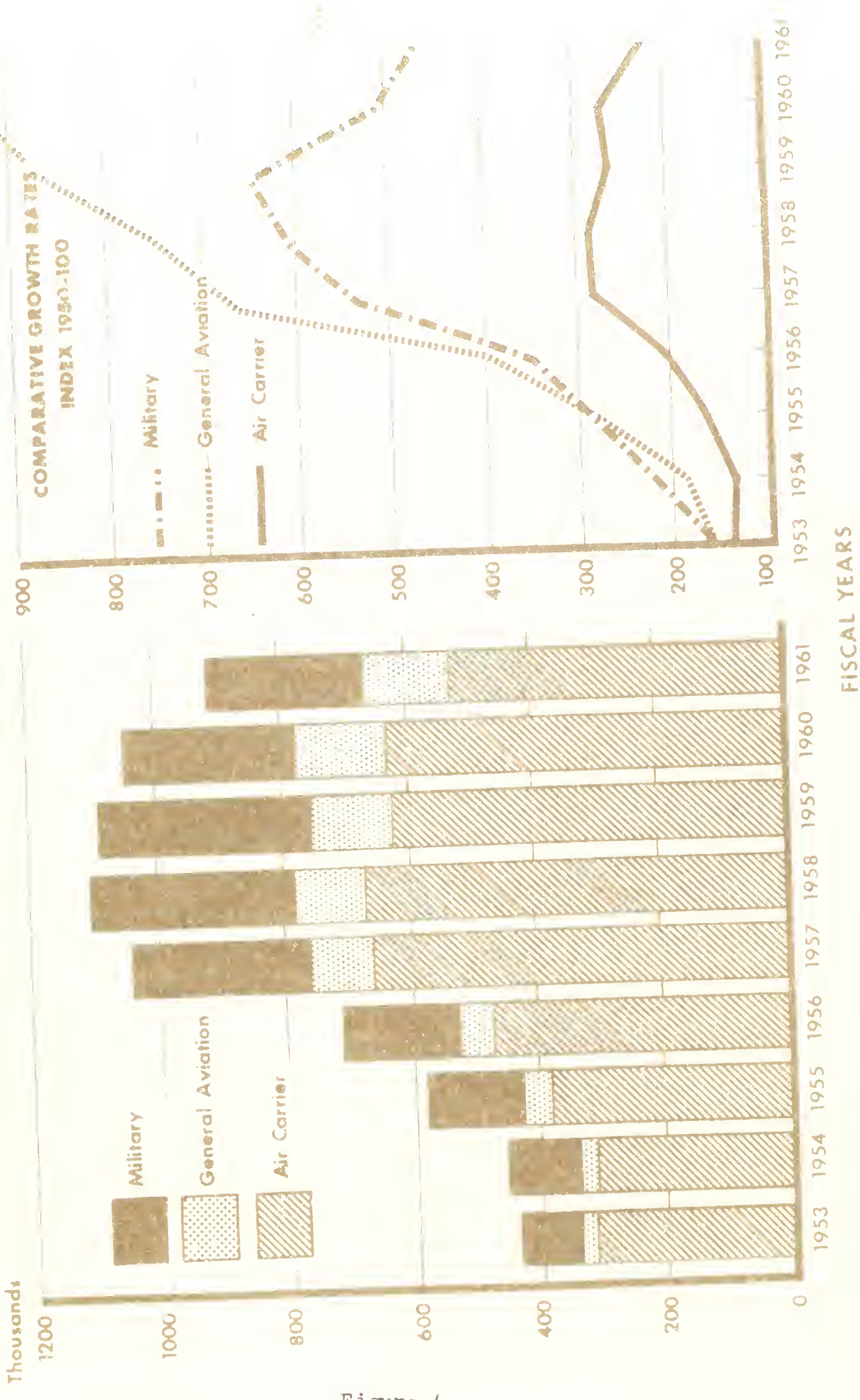
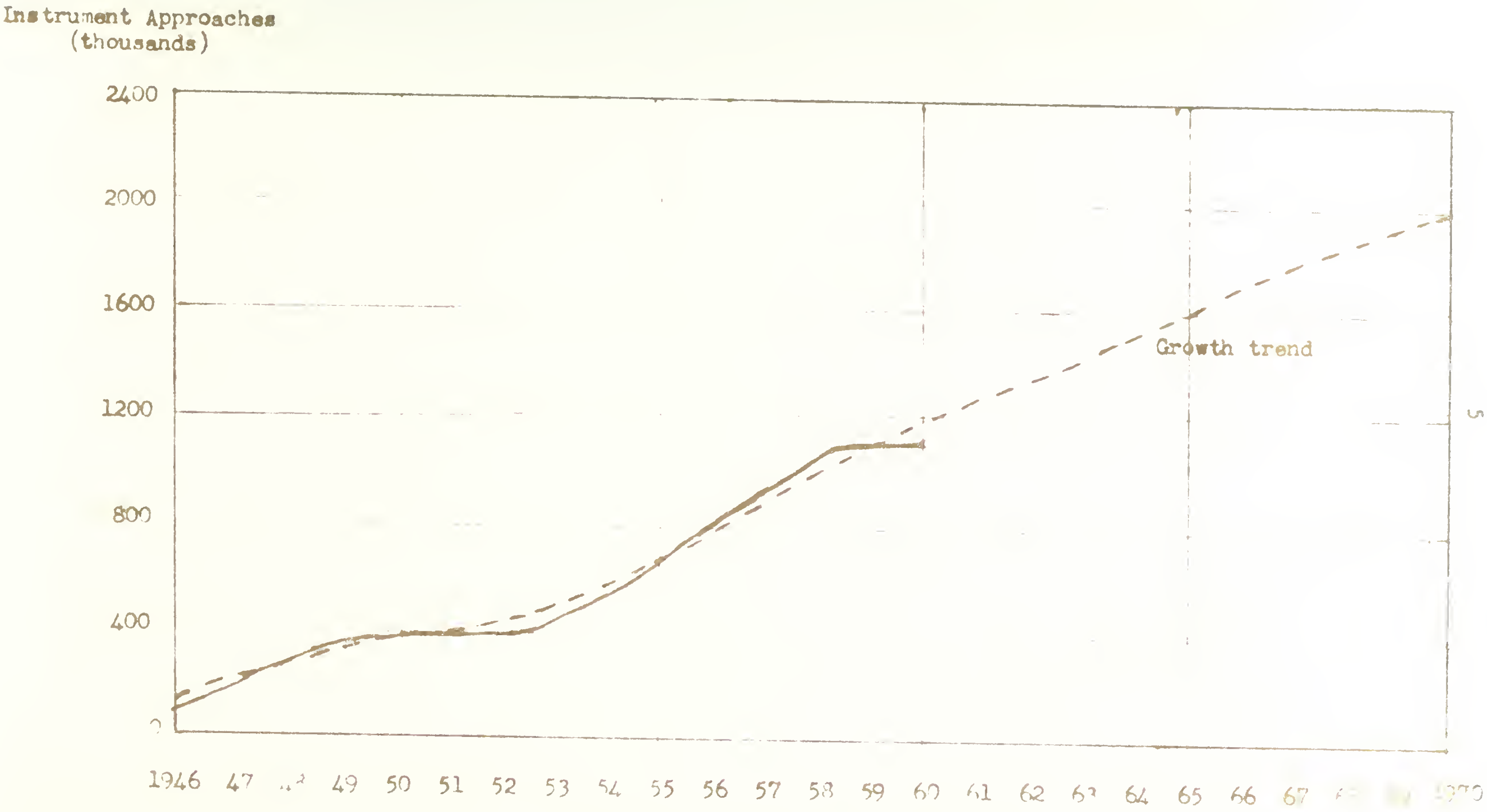

INSTRUMENT APPROACHES
REPORTED BY FAA AIR ROUTE TRAFFIC CONTROL CENTERS
FISCAL YEARS 1953-1961
Thousands
1200
1000
800
600
400
200
0
Military
General Aviation
Air Carrier
1953
1954
1955
1956
1957
1958
1959
1960
1961
FISCAL YEARS
COMPARATIVE GROWTH RATES
INDEX 1953=100
Military
General Aviation
Air Carrier
900
800
700
600
500
400
300
200
100
1953
1954
1955
1956
1957
1958
1959
1960
1961
FISCAL YEARS

Figure 4



Forecast of Instrument Approaches
196- -- 1970
Within FAA Air Route Traffic Control Center Areas

Figures derived from FAA Air Traffic Activity, Fiscal Year 1961

Figure 3

TOTAL MILITARY OPERATIONS
Fiscal Years 1952-1961

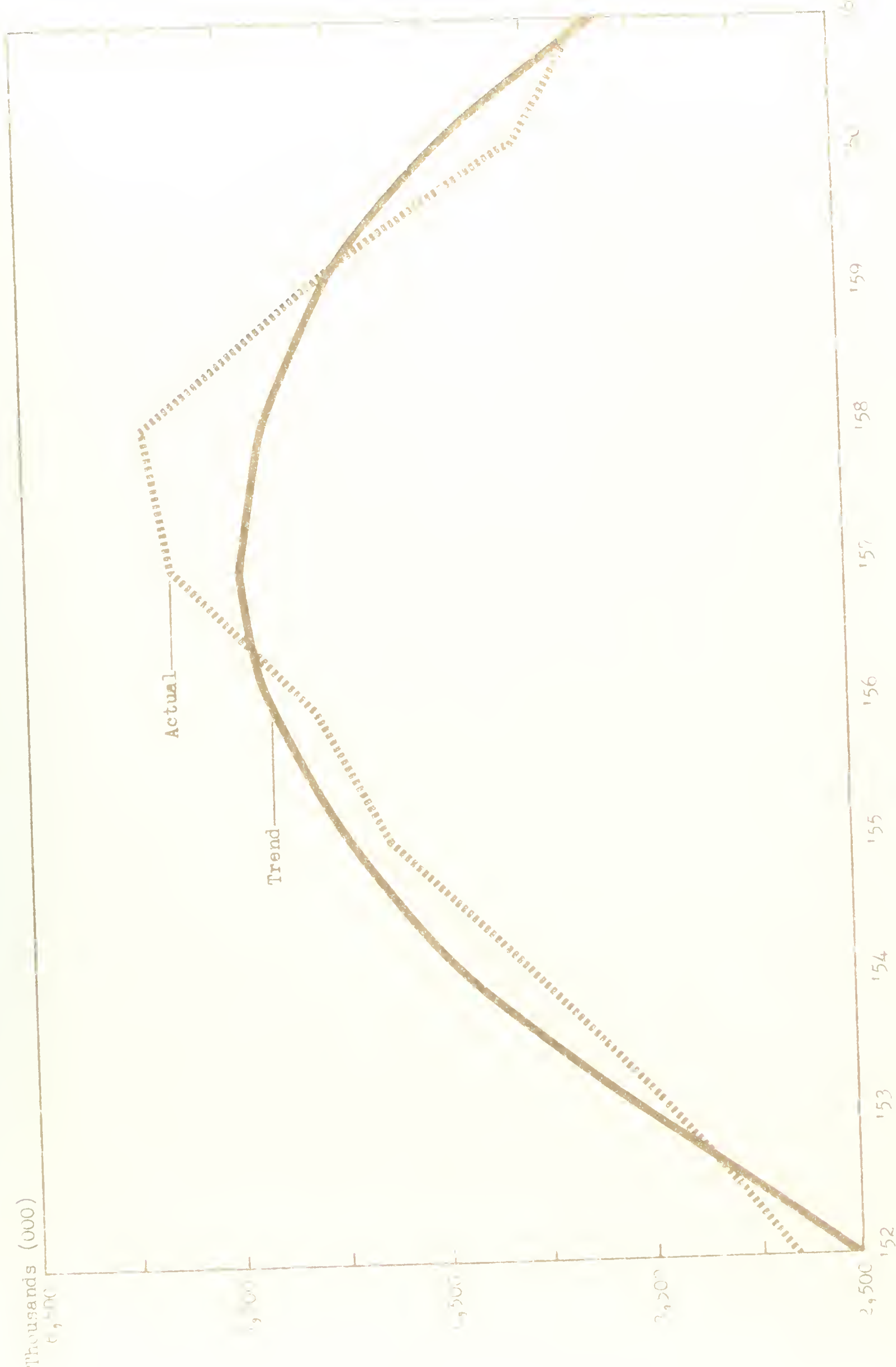


Figure 5

The anticipated 1975 performance spectrum of civil and military aircraft will range from sea level altitude and zero airspeed to over 100,000 foot altitude, and speeds greater than MACH 3 (about 2100 MPH). Project Beacon reports that there will be an anticipated 100% increase in Instrument flight rule (IFR) flying by 1975.[2] Interestingly enough, helicopter flying by 1975 is expected to increase by 300%. Although the total number of flights by 1975 is predicted to be about one and one-half times that of today, IFR traffic is predicted to double. In 1960, about 50% of all air carrier flights were made on IFR flight plans. By 1975 it is estimated that approximately 70% of all air carrier fixed wing flights will be flying under IFR.

At the present time, except for tower control of visual flight rules (VFR) aircraft at controlled airports, and the advisory services of the former military flight service centers, only IFR traffic is handled by the FAA traffic control system. This traffic is predicted to double by 1975. If the proposal by Project Beacon[3] is effected, that is -- all higher altitude flying and some VFR itinerant aircraft flying on very dense airways are brought into the control system, then the total controlled traffic will be about four times that of today.

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[2] Project Beacon, Report of Task Force on Air Traffic Control, FAA, October 1961, p. 9, U. S. Government Printing Office, 1961.

[3] Ibid.,

Statistics thus far presented serve only to indicate the degree of growth which has been experienced and what can be expected by 1975. An indication of the increase in air <u>terminal</u> traffic will provide a better insight into the magnitude of air operations. In 1955, there was a total of 4.3 million air terminal IFR operations. It is anticipated that by 1975 there will be 13.8 million IFR terminal operations.* Further compounding the workload and complexity of air control will be the VFR operations. In 1955, there were a total of 62.4 million terminal operations and by 1975, it is anticipated that there will be 96.7 million. Of this total, helicopter operations in 1955 were 2.5 million and by 1975 should be 15.2 million.

To the layman, these figures would appear staggering. As a matter of fact they are! It has been reported, and personal experience has confirmed, that the enroute system, as presently operating, is not overloaded. However, if the statistics are valid, the present system will be overloaded within a few years. This anticipated overload will be caused by dependence on separation standards calculated on pilot reports rather than ground radar control. Most serious is the mixture of IFR and VFR traffic along the high density airways, particularly in view of the high speed of many aircraft. There are also problems of radio frequency congestion, and pilot and controller overload due to the requirement of very frequent pilot-position reporting. The use of automatic data processing in all flight control centers should reduce the requirement for the frequent radio position

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* Terminal operations are forecasted on the following basis: takeoff and landing, one operation each; low pass missed approach and tough and go, two operations each.

reporting. Concurrently, the use of full coverage radar will materially reduce the odds of aircraft collisions and "near-misses".

At the present time, the greatest need for ADP is in high-density terminal areas. The attainment of safety and efficiency is most difficult in these areas due partially to inadequate and overloaded airports. Consider for a moment the problems involved in handling 60 aircraft movements (take-offs and landings) in one hour. This is the equivalent of one aircraft either arriving or departing each minute. During peak operations, Washington, D. C,, Approach Control handled upwards to 60 movements per hour and it was reported on one occasion that 80 aircraft movements were handled.[4]

The use of computers in the air traffic control system is sound and should be continued. Immediate benefits to be derived by the use of computers in terminal areas are:

1. More legible flight strips (previously flight strips were hand-written and one doesn't have to stretch the imagination too far to visualize the scrawling that occurs during peak hours of IFR traffic handling).

2. Accuracy - Computation of times between fixes are far more accurate and with practically no errors.

3. Education - Air controllers are becoming familiar with computer usage and greater application of the computers should result.

4. Safety - Increased accuracy and more legible flight strips help increase the safety margin.

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[4] Conference with Washington, D.C., ARTCC Personnel on 7 March 1961.

Changes in data processing and air-controller methods during the past few years are just the beginning. Later, we shall look to the future with the knowledge that we have only scratched the surface in this changing area. Progress in ADPS will not make all present systems and control techniques obsolete. It will make knowledge of ADP essential for all levels of personnel working with ATC; those who must rely on the information received -- the pilots, and those who transmit the information -- the air controllers.

Brief History of Air Traffic Control

Picture a rainy day at Newark Airport in the late 1920's. Visibility is about one mile and low, grey clouds are hanging at 200 feet. Two ticket agents of different airline companies are swapping "sea stories" over a cup of coffee. The first casually mentions, if his flight 57 will arrive on time today. The second agent, in a sudden spasmodic action, spills his coffee while anxiously asking, "What time today? We also have a flight due in." Both agents are now more than anxious but after comparing notes, discover that the flights are sufficiently far enough apart in time, that collision is improbable -- provided each flight arrives at its scheduled time. Frantic 'phone calls follow, arrival times are definitely established and the crisis abates - temporarily.

Newark Airport, Newark, N.J., conducted the first efforts at flight guidance and control. The authorities found it necessary, for safety, to establish local regulations and provide signalmen when the

air traffic increased to a point where aircraft could interfere with each other. Meanwhile, as aviation grew, traffic between cities began to follow fairly closely defined routes -- the shortest line between these cities -- which came to be designated and marked as airways. In other words, the air traffic itself, actually "built" the airways. When traffic along the airways increased in density, congestion occurred where the airways converged toward busy airports. The major users of these airports -- the airlines -- therefore organized airway traffic control offices to "pick up" the traffic along the approaching airways in bad weather and assign "safe" altitude levels for use until the airport traffic controllers could see the aircraft and guide them in for landing. By this time, of course, radio was used in conditions of low ceiling and poor visibility, for transmission of instructions to aircraft. Additionally, the airways were largely marked with radio ranges and lights defining their courses.

By 1936, it was apparent that a unified system of guidance was needed for the growing airway traffic. Because of the longer non-stop flights, congestion extended farther out from the airports and over state lines. It was during this year that enroute airway traffic control was taken over by the Bureau of Air Commerce of the U. S. Department of Commerce. Airport traffic control was left to each individual airport to handle. The Bureau of Air Commerce was succeeded by the Civil Aeronautics Authority (CAA) and in 1958 by the Federal Aviation Agency(FAA). The CAA was created by the Civil Aeronautics Act of 1938, and was a bureau

of the U. S. Department of Commerce. Subsequent reorganizations created two separate bodies, the CAA and the Civil Aeronautics Board (CAB). The Administrator of the CAA and the five members of the CAB are Presidential appointees. Broadly speaking, the CAB prescribes safety standards, investigates accidents, and issues certificates of public convenience to air carriers. The CAA carried out the safety regulations prescribed by the CAB, promoted development of air traffic and, among many other tasks, carried out the responsibility for controlling air traffic, both enroute and terminal.

In a successful effort to coordinate all air traffic control and separate the aviation agency from the Department of Commerce, President Eisenhower, on August 23, 1958, signed into law the Federal Aviation Act of 1958. This act created the Federal Aviation Agency (FAA). This independent agency, headed by a Presidential appointed administrator who reports directly to the President, brought together into one organization the CAA, the Airways Modernization Board, and the safety rule-making authority of the CAB. Under the law, personnel from the armed services are assigned key positions in the agency's organizational structure to assure proper coordination and cooperation between civilian and military activities.

Some statistics will provide an insight into the size and scope of the FAA activities in air control.

The FAA, with its six regional offices (Figure Six) operates over 219,000 miles of airways, which are 10 miles wide and extend upwards from altitudes of 700 feet. The airways are served by about 35 air

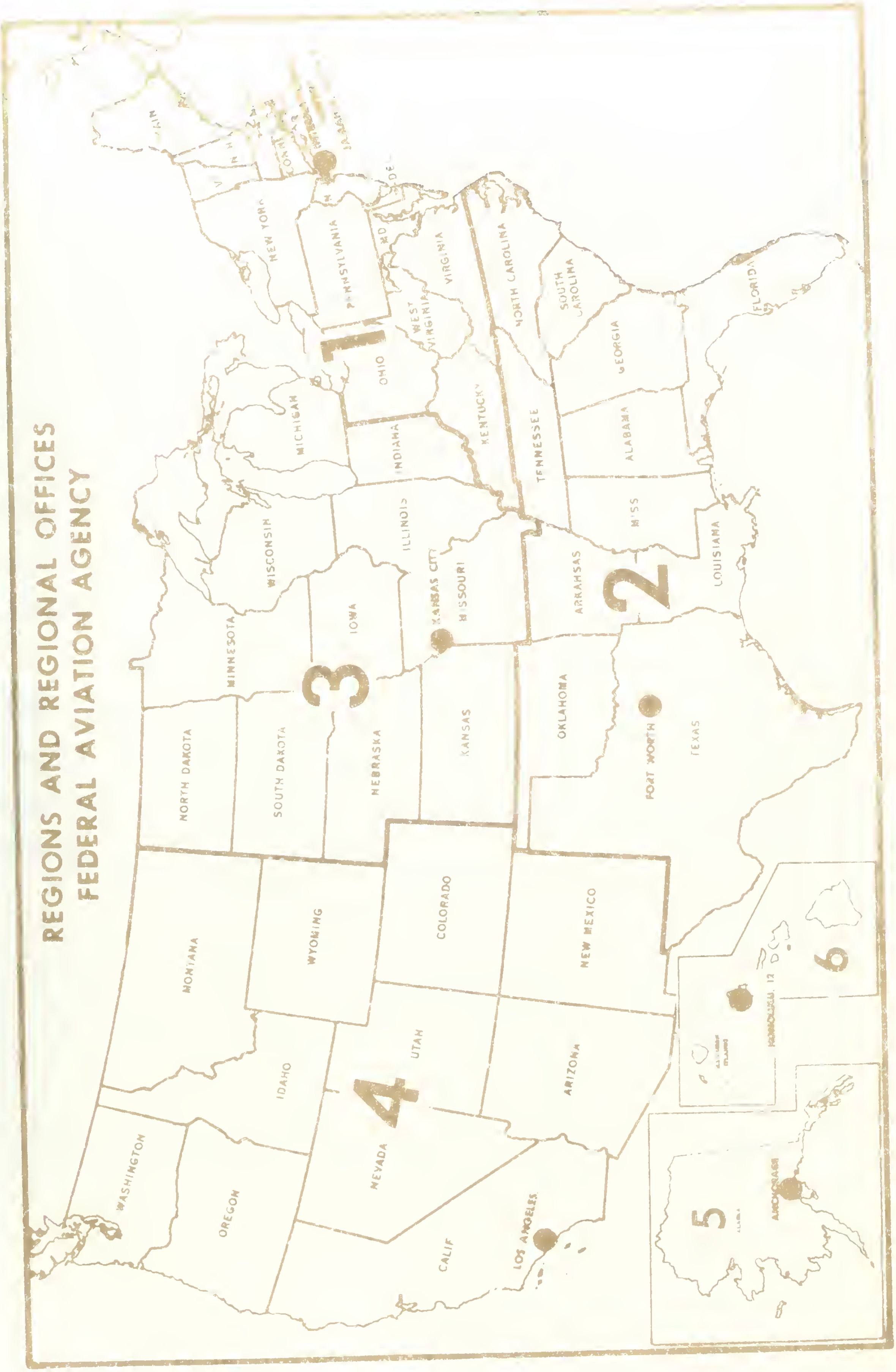
REGIONS AND REGIONAL OFFICES
FEDERAL AVIATION AGENCY
NEW YORK
PENNSYLVANIA
OHIO
WEST VIRGINIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
FLORIDA
MICHIGAN
INDIANA
KENTUCKY
TENNESSEE
ALABAMA
ILLINOIS
WISCONSIN
MINNESOTA
IOWA
KANSAS CITY
MISSOURI
ARKANSAS
MISS
LOUISIANA
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
FORT WORTH
TEXAS
MONTANA
WYOMING
COLORADO
NEW MEXICO
IDAHO
UTAH
ARIZONA
WASHINGTON
OREGON
NEVADA
CALIF
LOS ANGELES
1
2
3
4
5
6

Figure 6

air route traffic control centers (ARTCC), which provide enroute guidance to aircraft flying on instruments. Terminal traffic control is provided by air controllers in over 300 airport towers. The magnitude of the workload handled by the FAA ARTCC's is shown in Figures 7, 8, 9, and 10. Figure 7 graphically illustrates the proportions of hours flown by General Aviation in fiscal 1960 -- note the size of the pie taken by rotorcraft (helicopters). Later in this chapter we will see how this particular segment is forecasted to grow. Figure 8 illustrates the declining numbers of relatively low performance, two engine aircraft and the increasing numbers of four-engine, particularly tubo-jet, aircraft for the period 1954 - 1960.

Figure 9 shows the total aircraft operations for fiscal years 1952 - 1961. As is graphically indicated, the trend is rising. This trend is also reflected in Figure 10, which shows the total air carrier (passenger operations vis-a-vis general aircraft operations) operations for the period fiscal years 1952 - 1961.

Figure 7

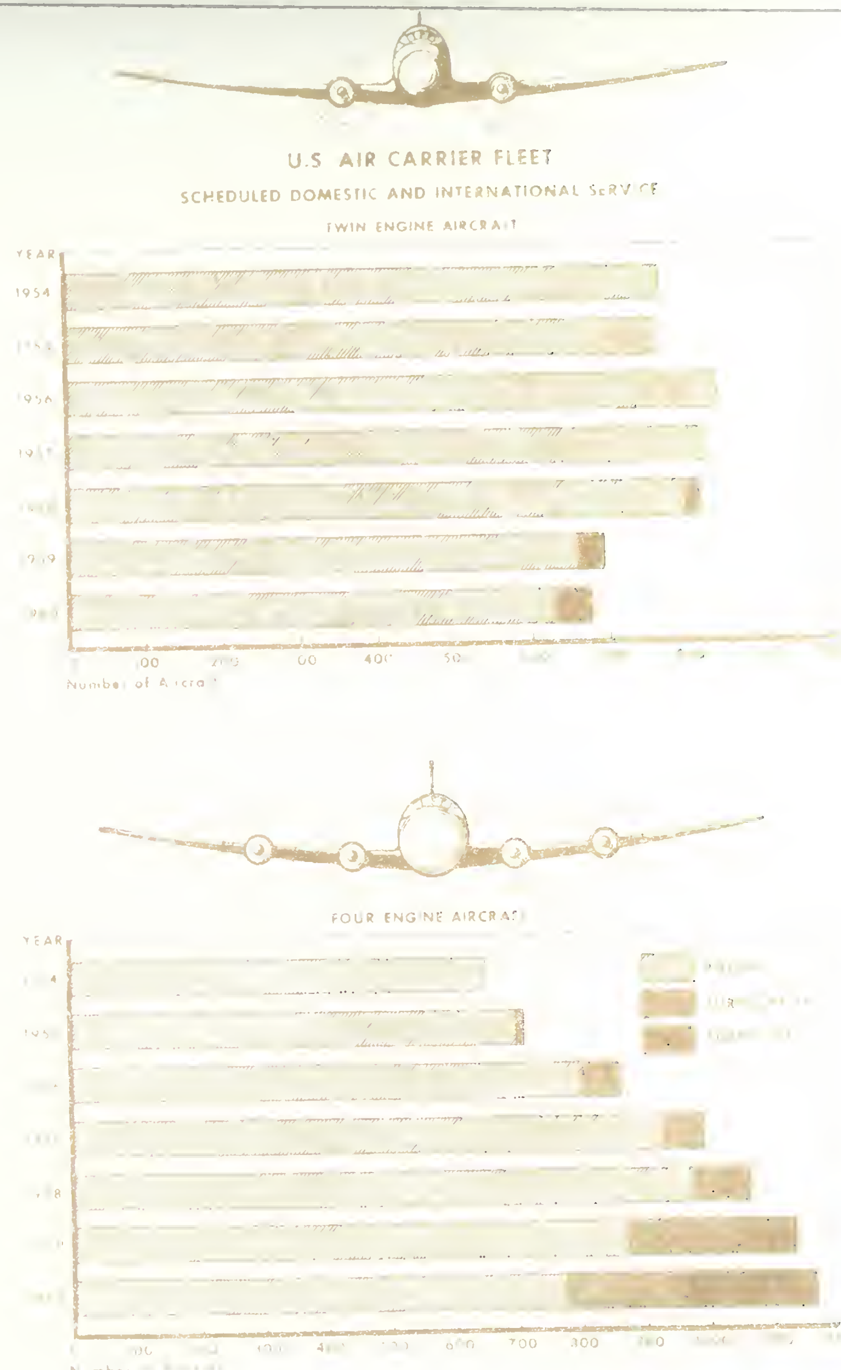

Figure 8

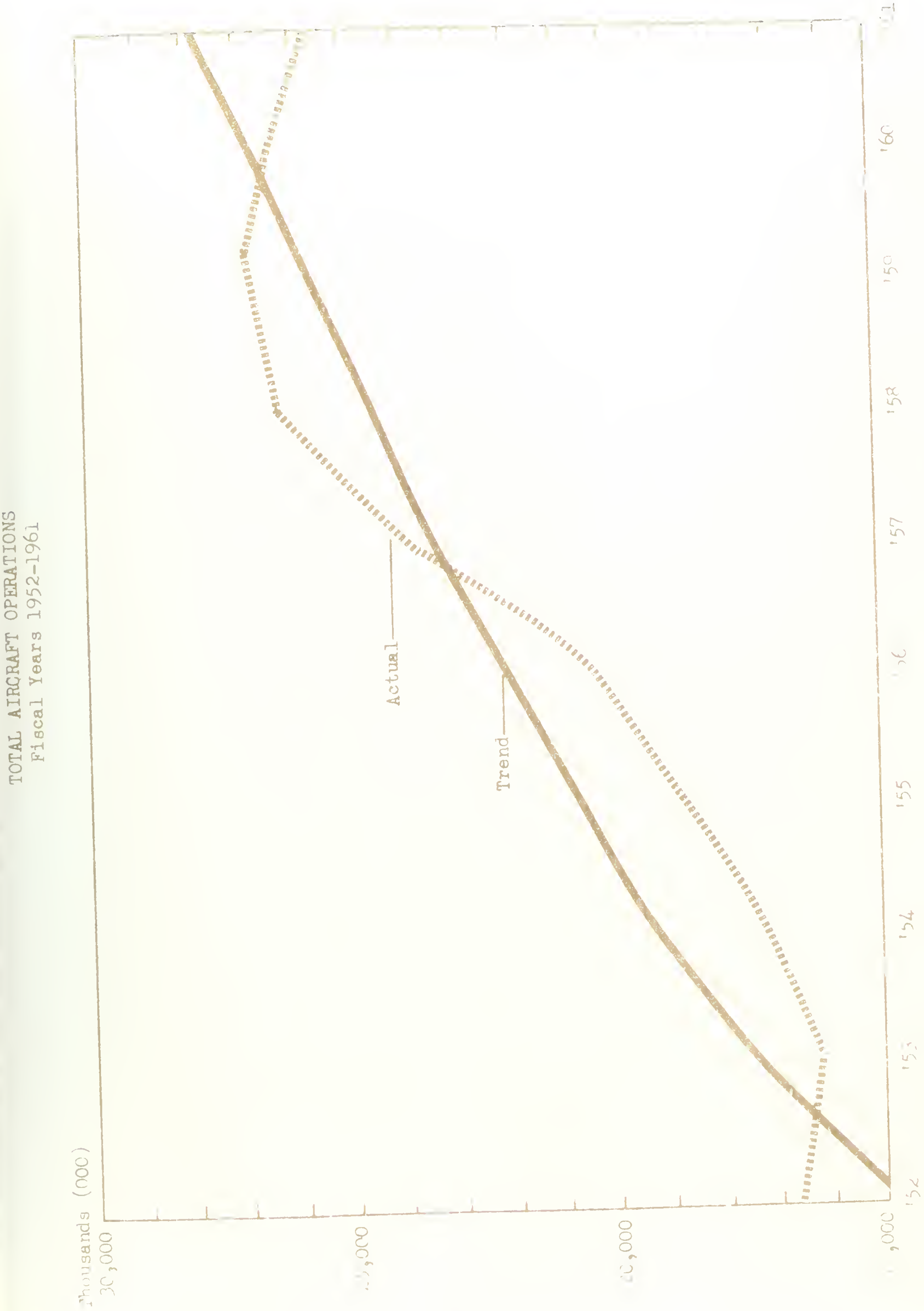
TOTAL AIRCRAFT OPERATIONS
Fiscal Years 1952-1961
Thousands (000)
30,000
20,000
Actual
Trend
'54
'55
'57
'58
'60

Figure 9

TOTAL AIR CARRIER OPERATIONS
Fiscal Years 1952-1961

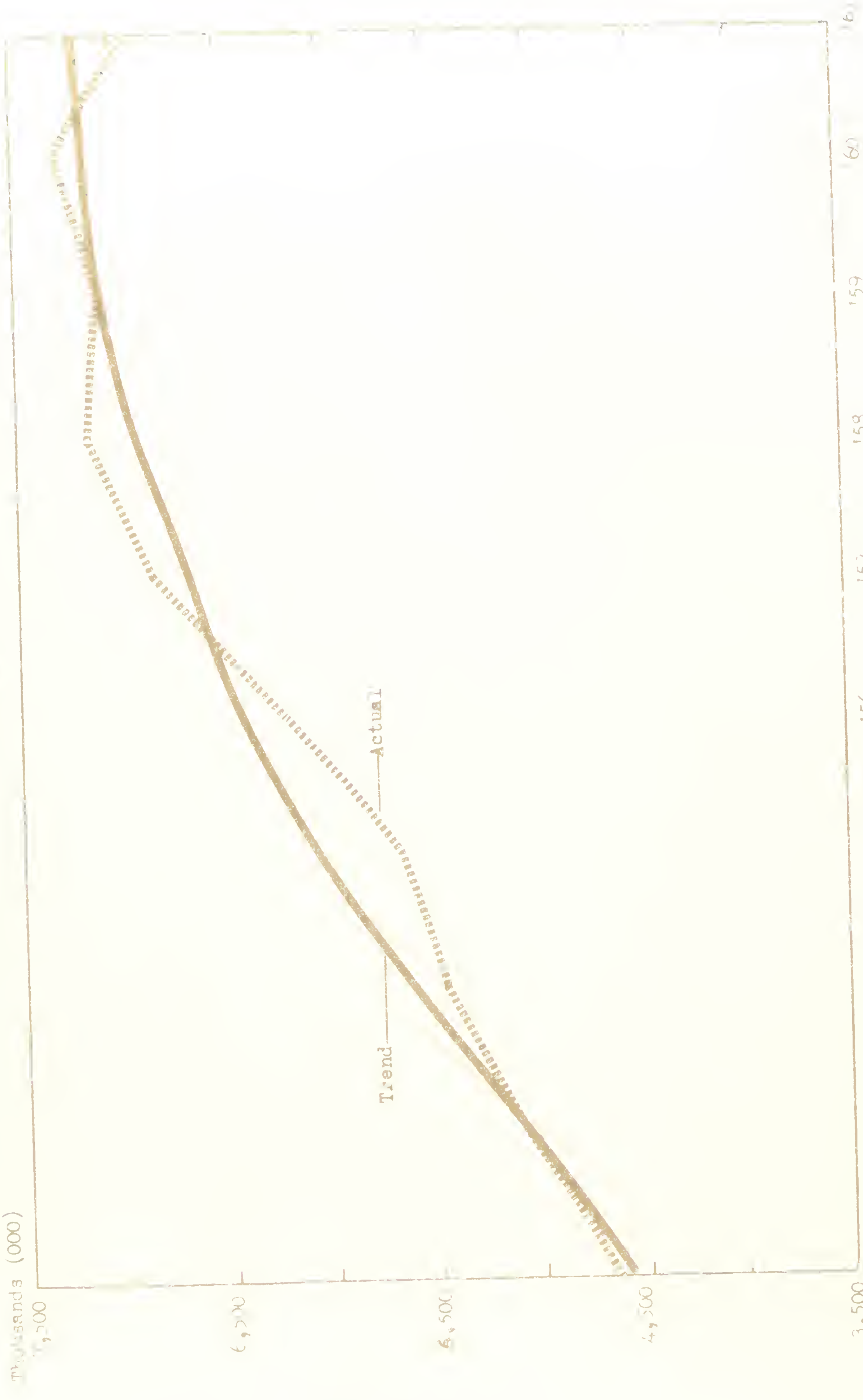

Figure 10

FAA ARTCC are linked by over 175,000 miles of interphone lines and over 114,000 miles of teletype circuits through which air traffic control data are transmitted.

Key navigational aids along the federal airways are the very high frequency directional radio ranges (VOR's) and the combination civil VOR and military tactical air navigation system TACAN (VORTAC).

To aid air traffic controllers in monitoring flights along federal airways, the FAA has stepped up its long-range radar installations program. Approximately 50 long-range radars, capable of detecting aircraft within a 200 mile range and up to 60,000 feet in altitude, are presently in use or under construction. In addition to the civil long-range radars, studies are being conducted to determine the feasibility of incorporating the USAF aircraft early-warning radar net (SAGE) into the FAA's ARTCC. Thus far, the preliminary studies indicate that the radar segment of SAGE can be integrated effectively. However, computer installation and its incorporation in the ARTCC complex, requires further study.

The FAA's airport surveillance radars, which can detect aircraft within a 50-60 mile radius, up to altitudes of about 25,000 feet, now number in excess of 80. Additional terminal area radar installations are under construction.

Low frequency radio ranges homers and the now defunct airways lighting system are being phased out wherever possible. Newer, more

reliable and accurate systems, such as the VOR and VORTAC, have in the main, replaced the low frequency equipment.

ADPS in use by the FAA to assist in controlling air traffic are installed at the following locations:

	Location (ARTCC)	Type
1.	Boston	UNIVAC
2.	New York	"
3.	Cleveland	"
4.	Pittsburgh	"
5.	Washington, D. C.	"
6.	Indianapolis	IBM

The Indianapolis IBM installation is planned for conversion to a UNIVAC system in the very near future. It is noteworthy, that the ARTCC with the greatest volume of air traffic, have the ADPS installed -- future expansion to other centers is a matter of time and available capital. The need exists now.

Other facilities, such as the instrument landing systems (ILS), ground controlled approach (GCA), high intensity approach lights, high speed turnoffs on runways, improved radio discipline and equipments, plus the six installations of automatic data processing equipments are the means by which FAA control, more efficiently, the ever increasing numbers of civil aircraft presently crowding the sky.

II. Examples of Various Characteristics of Aircraft Utilizing Terminal Approach Control Facilities with Emphasis on the Helicopter

The following will help the layman understand one of the operational limitations imposed on the controlling of air traffic. The limitation discussed is the various operational characteristics of different aircraft.

In larger terminal areas, such as Washington, D.C., New York, Chicago, and Los Angeles, the greatest hazards are present during periods of marginal IFR weather. That is, during the periods of time when aircraft are flying under IFR and VFR conditions. It must be remembered that pilots flying under VFR provide their own separation and pilots flying IFR are provided separation from other IFR traffic but not other VFR traffic. This most serious problem area results not only from the concentrated volume of traffic but from the mixture of continuously climbing and descending VFR and IFR aircraft of widely varying performance capabilities. Take, for example, the differences in performance characteristic of the Boeing 707, four engine, pure jet airliner and the Beechcraft D-18, two-engine, six place utility aircraft (Figures 11 and 12). The figures used below are approximates since airspeeds will vary due to aircraft weight, pilot technique, aircraft configuration, etc.

	Boeing 707	Beechcraft
Cruising A/S	500 MPH	150 MPH
Climbing "	220 "	95 "
Landing "	170 "	80 "
Descending "	210 "	90 "

Figure 11

Beechcraft Super 18

(Photo courtesy of Beechcraft)

The Beechcraft Super 18 is a modified version of the old, familiar twin-engine "Beech". This version is an eight-place, executive transport with a top speed of 234 MPH and a range of 1,455 miles. It is produced by the Beech Aircraft Corporation, Wichita 1, Kansas.


N190

BEECHCRAFT Super 18

Eight-Place, Twin-Engine Executive Transport

Top Speed — 234 mph. Range — 1,626 miles

BEECH AIRCRAFT CORPORATION
WICHITA 1, KANSAS

Figure 12

BOEING 707 - 320 B

(Photo courtesy of The Boeing Company)

Pictured is a Boeing 707 - 320 B, Turbofan, Intercontinental airline. Powered by four 18,000 pound thrust Pratt & Whitney turbofan engines, this new jetliner has a gross weight of 317,500 pounds. It has a maximum passenger payload range, with normal reserves, of more than 6,000 miles. This jetliner is the newest and longest-range passenger airliner in the Western free world. 707 - 320 B's are being flown by Pan-American World Airways, Air France, Lufthansa-German Airlines, Trans-World Airlines, and others. They are in quantity production by The Boeing Company, Seattle 24, Washington.


BOEING 707
N709PA
707

Photo by

BOEING AIRPLANE COMPANY

Box 3707 Seattle 24, Wash. -- Wichita 1, Kansas

Credit Appreciated

In addition to and intermingling with the aforementioned aircraft are the old, familiar DC-3, 4, 5, 6, 7's, plus Martin 404, Lockheed Electra turboprops,* viscount turboprops and many others. A new arrival on the airways scene are the rotocraft -- helicopters.

This recent addition to the IFR flying clud is truly a versatile machine. The word is from the Greek Helix meaning "spiral", plus pteron meaning "wing". It is pronounced, contrary to many linguists pronounciations, "hell-i-copter." The helicopter has been an attractive, somewhat glamorous vehicle ever since it appeared as mode of travel. Since their acceptance as a means of airline transportation, helicopters have been restricted to VFR flying. In spite of this restriction, the scheduled helicopter airlines have become an integral part of the nation's domestic and overseas air transportation system. Over 94%[5] of those who fly on the helicopter airlines are interline passengers -- passengers going to, from or between airline flights. This means that most all helicopter passengers are traveling between cities in every state of the United States and abroad.

In today's jet age all-weather helicopter service is more important than ever. The en-route speed of the pure jet emphasizes the relative slowness of surface travel. What gain to cross the continent in five hours and then spend two hours traveling downtown

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*Turboprops equipped aircraft utilize a jet engine, geared down to accommodate the conventional propellor.

[5]Air Transport Advisory Ltr., Volume VIII, No. 1, p. 2, 7 March, 1962.

from the airport? The operating characteristics of the helicopter enable it to hover at zero airspeed, climb and descend vertically, remain at zero airspeed or fly off at speed in excess of 150 MPH. Recent speed trials of the twin turbine, Vertol 107 and the twin-turbine, Sikorsky S-61 (Figures 13 and 14) are evidence that this type helicopter can fly in excess of 200 MPH! It is this versatility that gives it such a promising future as part of our national and international air transport system, as well as part of the local transportation system of every community.

It has been demonstrated, time and again, that helicopters are able to initiate landing approaches from any geographical direction and then manuever to a landing while remaining over a small surface area.* As a result, helicopters can be handled efficiently during VFR weather at busy airports when major runways are in service, without conflicting with conventional aircraft operations. During VFR weather, they can use airspace not suitable for fixed wing aircraft. In the terminal areas, helicopters can fly at altitudes from 300 - 500 feet and enroute, from point to point, they can cruise at (generally) 300 to 1000 feet.

From the above discussion, we can deduce that helicopters have earned an enviable position in the air transport field. In fact, as far back as 1958, scheduled helicopter operations represented 16% of the total air carrier movements of all airlines serving LaGuardia Airport.[6]

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* The President of the U.S. utilizes helicopters extensively to reduce enroute time between distance areas, e.g., between the White House lawn and Andrews AFB, Md.

6 Project Beacon, Federal Aviation Agency, Oct. 1961, p. 28.

Figure 13

BOEING VERTOL 107

(Photo courtesy The Boeing Company)

The Boeing Vertol 107 was the first turbine powered helicopter to land at the new downtown heliport in New York City, after dedication of the heliport on December 8, 1960. The Port of New York Authority heliport is near the foot of Wall Street, Pier 6, on East River. It will be connected with airports in the New York area by helicopters operated by New York Airways. Aircraft such as these have made possible VFR flights from the heliport to New York International Airport in only seven minutes, carrying 25 passengers at 150 miles per hour. The Vertol 107 is an all-weather, day and night operating aircraft, powered by two General Electric CT-58, gas-turbine engines; it is the first transport helicopter with the ability to climb vertically from takeoff and descend vertically to land as a matter of routine operation, regardless of wind direction. The Vertol 107 is produced by The Boeing Company, Vertol Division, Morton, Pennsylvania.


NEW YORK

SIKORSKY S-61

(Photo courtesy of Sikorsky Aircraft Company)

The Sikorsky S-61 is a two-engine gas-turbine powered helicopter. It is capable of all-weather, day or night, operation. Los Angeles Airways has accepted delivery of the S-61 for use in its authorized area as a passenger/mail delivery air vehicle. This version of the S-61 is capable of emergency water landings and can fly on one engine, if necessary. The Sikorsky S-61 is produced by United Aircraft Corporation, Sikorsky Division, Stratford, Connecticut.


CHICAGO HELICOPTER AIRWAYS
N301Y

On many occasions, military helicopters have conducted IFR flight under actual instrument conditions. Inauguration of IFR flying for scheduled civilian helicopter airlines is close at hand. The two major improvements in the new helicopters -- twin-engine capability and higher speeds have substantially increased their safety margin. The major obstacle to be overcome is enroute and terminal navigation. It is granted that the helicopter can fly the normal (conventional) airways and utilize conventional terminal procedures. However, the unique usefulness of the helicopter is downgraded, if the helicopter has to adhere to these conventional rules. The inherent delays caused by holding patterns, IFR clearances, VOR approaches, etc., would be wholly incompatible with the relatively short flight times of the typical helicopter routes.

All three of the FAA certified helicopter airlines have ordered the new twin-turbine, rotary-wing aircraft.[7] Los Angeles Airways has already placed the first one in service. In general, the three airlines have been authorized to provide service within a 50 to 60 mile radius of the metropolitan areas in which they operate. Within these areas, they offer service from airport to airport, as well as between airports and business centers. In addition, service is provided to suburban communities which fall within their authorized area of operations. In total, these airlines provide service to about 60 locations.

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[7] Los Angeles Airways, Chicago Airways and New York Airways.

Although scheduled helicopter service was initially established for the purpose of carrying mail and cargo, the carrying of passengers quickly became the most important source of revenue. As an indication of the imperative need for all-weather, IFR, helicopter capability, it would be pertinent to point out the meteoric rise in passenger traffic. In Calendar Year 195e, there were 1,227 passengers who availed themselves of services of the embroyonic helicopter airlines. By 1960, 480,579 passengers were implaned in "helos." A phenomenal growth in less than eight years of operation! During this same period, cargo operations increased almost proportionately. Measured by passenger traffic, Chicago helicopter airways is by far the largest of the three airlines, with New York and Los Angeles in second and third place. (See Figures 15, 16, and 17 for a brief history of these 3 airlines).

Chicago's passenger traffic between Midway and O'Hare airports boomed with the inauguration of jet flights at O'Hara. Total passenger traffic in 1959 was nearly four times the 1957 level. During this same period, helicopter passenger traffic increased 76% in New York and 40% in Los Angeles. Passengers now account for 84%, of the total revenue ton miles flown by the three helicopter airlines. Table 1 shows the comparison of growth between domestic airline (fixed-wing) traffic and helicopter airline passenger traffic for the period 1953 - 1960.

TABLE 1

DOMESTIC SCHEDULED AIRLINES

Passenger Service (1953 - 1960)[1]

Year	Fixed Wing Aircraft	% Change	Growth[2]	Helicopter	% Change	Growth[2]
1953	2,612,767		100	1,227		100
1954	2,660,579	1.8	102	8,431	590	690
1955	2,901,758	9	111	29,179	256	2,380
1956	3,094,075	6.5	118	63,535	118	5,340
1957	3,318,282	7.2	127	158,187	148	12,950
1958	3,176,102	4.3	121	209,880	32.6	22,100
1959	3,420,682	7.5	131	366,315	74.9	29,800
1960	3,343,989	2.2	128	480,579	31.2	39,200

[1] Passenger totals obtained from the FAA Statistical Handbook, 1961 Edition, FAA, p. 116. U.S.Government Printing Office, Wash.,D.C.

[2] 1953 base year = 100

CHICAGO HELICOPTER AIRWAYS, INC.
5240 West 63rd Street
Chicago 38, Illinois

SERVICE

November 24, 1948	:	Certificated by the Civil Aeronautics Board (as Helicopter Service, Inc.) to serve the Chicago metropolitan area.
August 17, 1956	:	Inaugurated scheduled air mail service.
November 12, 1956	:	Scheduled passenger service began.
February 26, 1962	:	Beginning of scheduled air express service.

EQUIPMENT

1949 - 1955	:	Service provided by six Bell 47-B's.
1955 - 1956	:	Bell 47-B's replaced with Bell 47-G's.
1956	:	Three Sikorsky S-55's added to fleet.
1957 - 1959	:	Five S-58's acquired (three S-55's retired).
1959 - 1960	:	Three additional F-58's added to fleet (four Bell 47-G's retired).
1962	:	Four S-61's on order.
Current Status	:	Two Bell 47-B's; seven S-55's.

Figure 15

NEW YORK AIRWAYS, INC.
Box 428
LaGuardia Airport Station
Flushing 71, New York

SERVICE

March 13, 1952	:	Received a certificate from the Civil Aeronautics Board to furnish scheduled helicopter mail, cargo and passenger service to the metropolitan New York area.
October 15, 1952	:	Inaugurated scheduled mail service.
January 26, 1953	:	Began freight service -- the first scheduled helicopter air freight service in the world.
July 8, 1953	:	Initiated the first regularly scheduled passenger helicopter service in the world.

EQUIPMENT

1952-53	:	Took delivery on five (Sikorsky) S-55's.
1956	:	Three S-58's added to fleet, one Bell 47-H (for charter work).
1957	:	Five Boeing (Vertol) V-44's added. (All Sikorsky equipment retired.)
1959	:	Bell 47-J replaced 47-H. Currently used for both charter and sightseeing.
1962	:	Four V-107's (twin-turbine equipment) to be placed in service during the year.
Current Status	:	One Bell 47-J; five Boeing V-44's.

Figure 16

LOS ANGELES AIRWAYS, INC.
5901 West Imperial Highway
Los Angeles 45, California

SERVICE

May 20, 1947	:	Certificated by the Civil Aeronautics Board to serve the metropolitan area of Los Angeles, thus becoming the world's first scheduled helicopter airline.
October 1, 1947	:	Began scheduled air mail service by helicopter - the world's first.
December 17, 1953	:	Introduced the world's first scheduled helicopter air express service.
November 22, 1954	:	Inaugurated scheduled passenger service.

EQUIPMENT

1947 - 1948	:	Service provided by five Sikorsky S-51's.
1953 - 1954	:	Five S-55's added to fleet (four S-51's retired).
1960	:	One S-62 (single-engine turbine) added to fleet.
March 1, 1962	:	Two S-61's (twin-turbine equipment) went into service. Two more scheduled to go into service during 1962.
Current Status	:	Two S-51's; three S-55's; one S-62; two S-61's.

Figure 17

The public acceptance of helicopter service is evident in the growth of helicopter airline traffic over the years. This impressive growth to date has been achieved with single-engine helicopters, which as has been pointed out, have been severely limited by instrument (IFR) weather. The new twin-engine, longer range, more stable equipment being placed into service will greatly improve the IFR weather capability of the helicopter airlines and make possible continued growth in traffic and public usefulness.[8]

In the future the preferred application of the helicopter, including other V/STOL aircraft, may prove to be as a replacement for the conventional fixed-wing, short haul aircraft. Intercity airport to airport transportation systems are largely antiquated. The special advantage of the helicopter over surface transportation is noticeably better. In addition to this speed advantage, the helicopter may impose a significantly lower load on the air traffic control system than conventional fixed-wing aircraft. This is due mainly because the helicopter can operate in corridors and channels different from those used by fixed-wing aircraft. It has been pointed out that the helicopter can operate at a much lower altitude and by use of a precise, navigation system, should be able to navigate more accurately by holding closer to a prescribed flight path than fixed wing planes. Since the helicopter does

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[8] Details of the forecasted growth of the V/STOL, including helicopter, industry may be found in Chapters IV and V of Project Hummingbird. The Helicopter and other V/STOL aircraft in commercial transport service. This report dated November, 1960 deals with the economic aspects of V/STOL aircraft. It was prepared under the auspices of the FAA, Washington, D. C.

possess these unique operational characteristics, they will therefore reduce departure and arrival air traffic control delays with consequent reduced terminal to terminal "block" times. Assuming the availability of a navigation system suitable for helicopter control, such as the British "Decca" system, it could be assumed that increased helicopter usage will not impose an additional workload on air traffic control but rather will reduce it, thereby reducing the need for very short-haul, fixed-wing aircraft.

The use of automatic data processing and its effect on air traffic control will be discussed in subsequent chapters. It is not difficult to appreciate the complexity of the air controller's dilemma. On one hand he must contend with a 500 + MPH jet airliner, and on the other, he must accommodate an 80 MPH helicopter. The magnitude of the job of solving air traffic control problems is immense -- automatic data processing can and does assist.

CHAPTER II

COMPUTER APPLICABILITY

Although automatic data processing will not in the foreseeable future place the air controller in "the role of a locomotive engineer watching gauges and dials, and then, pulling control levers," [9] it has and will continue to open new methods of operations and procedures. Unfortunately, associated with these new operations and procedures are many problems which will only be solved by an appreciation of what ADP can do. A brief introduction to ADP may prove beneficial. What it is, the history of its use in air traffic control and its present application will be discussed. Personnel considerations as they affect and are affected by ADP will be discussed in Chapter III. It is in this area that the greatest potential for growth lies.

Human understanding of the capabilities and limitations of ADP in the air traffic control arena is in need of expansion. Once the human distruct of the machine is overcome, greater strides may be taken. It has been the experience of management that on the initial installation of a data processing system, unfavorable employee reaction occurs as a result of the "grapevine". [10] Since the "grapevine" rarely carries with it any knowledge of the true nature of the project or its <u>ultimate</u> effect on the personnel within the organization, their jobs or security, the uninformed personnel become suspicious of, and anxious and even resentful toward the project. The initial installation of ADP

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[9] Wallace A. Bounds, "How Technical Future Management?" <u>Advanced Management</u>, October 1959.

[10] Winston C. Dale, "Getting the Best Results from Simulation", Business Management, October 1961.

in the traffic control centers did not reduce numbers of personnel. On the contrary, discussions with various personnel in the ADP section of the FAA disclosed that additional personnel were added to operate the machinery.

How and Why of ADP

How does ATC insure the safe, efficient movement of air traffic? How does ADP assist the air controller to guarantee this insurance? First, it may be worthwhile to describe ADP in detail.

The heart of the automatic data processing system is the central processing unit, called the computer. The computer has certain functional components which allow rapid data processing. (Recall the need for this rapidity of processing date.) These components are: input, storage, processing unit (either arithmetic or logic), control and output. At the present time, only the arithmetic processing unit is used in ARTCC. Since these terms are rather meaningless, let us compare their functions with those of a unit we know well -- our own human anatomy.

We have all, at one time or other, touched a hot stove burner. The sense of touch recognizes a change in temperature. This is input. All of our senses are input devices. The intricate nervous system of the body sends the various input impulses to the central nervous system which determines that one of many inputs has the priority so that priority input is sent to the brain. The central nervous system then can be compared to the control function of the computer. The brain interprets the impulse as one of pain (in the case of the burned finger)

and makes a decision; it sends an order back through the central nervous system to the muscles of the hand. The brain is performing a function similar to the processing unit of the computer. The muscles, in our example, are serving as the output. The hand is pulled away quickly almost before you realize that you have touched a hot object. The next time you see a stove, you will be less inclined to touch the burners, because at the same time your brain sent the information back to the muscles in your hand, it stored the impulse of pain and fear in a section we laymen call memory. This is similar to the storage unit of the computer.

The computer can receive input from a keyboard, punched-card, punched-paper tape or magnetic tape. This input consists of data and instructions which are placed in memory or storage section. The instructions may now enter the control unit where proper electrical circuits are energized. According to the instructions, data are acted upon in the processing unit. After the processing has been completed, the new data or information is sent to the output section. The output of this system may be in the same form as the input or in printed form.* Normally, the output of the system is what is required by the air controller. This output is printed on flight strips and passed to the appropriate controller for his use.

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* For a more sophisticated presentation, the reader may wish to read Electronic Data Processing, An Introduction, by Martin, Edley Wainwright, Jr., Richard D. Irwin, Inc. 1961.

A Brief Discussion on the Present Day System of ATC

In the first section of this chapter, we discussed ADP and the various components which comprise an ADP system. Now let us consider how ADP can assist in air control. An insight into the problems associated with ATC and how these problems are solved may assist the reader to a better understanding of how ADP is used for ATC.

The inputs to the computer are obtained from the requirements of safely controlling air traffic. For brevity, we will disregard VFR traffic and concentrate on IFR traffic. The technique of airway traffic control is to reserve for each aircraft a block of air into which no other aircraft may intrude, thus providing safety and preventing unorganized confusion. The size of the block of air required by each aircraft depends upon the limits within which the block can be maintained during flight. Its vertical dimension must be sufficient to prevent collision with another aircraft above or below. Usually, this dimension is 1,000 feet, but higher altitude aircraft are separated by 2,000 feet. Its length along the direction of flight is generally expressed in time, usually minutes, and with present day control procedures is usually ten minutes -- complete radar coverage can reduce this time considerably. The width of the block of air can be less than the width of the airway provided radar control or other electronic devices are in use which enable the pilot to perceive accurately his position along the airway. ATC, then, provides separation by:

1. Vertically -- assigning different flight levels.
2. Time -- denying the same altitude to any aircraft expecting to follow another at any point within a given period of time, and,

3. Laterally -- assigning specific airways.

In order to provide proper separation (block of air) for each aircraft, air control personnel must be able to pre-visualize the pattern which traffic will form at all times until all aircraft are on the ground. It is therefore vital that control personnel be provided with necessary information to establish the ever-changing traffic patterns. For this reason, ARTCC receive for each flight under their control, a proposed flight plan and progress reports enroute. The proposed flight plan, filed by the pilot, includes such items as:

1. Pilot's name
2. Aircraft identification
3. Point of departure and destination
4. Proposed cruising speed
5. Airway route to be flown
6. Altitude or altitudes requested for flight.

(See Figures 18 and 19 for a copy of the present-day flight plan submitted by pilots for a proposed flight).

Approval of this plan by an ARTCC, with such alterations as may be found necessary by the controllers, is a guaranty to the pilot that his flight has been checked against other IFR flights and that his reserved block of air is assured.

Progress reports, showing time and altitude, must be made by the pilot as the aircraft passes over each fix enroute so that a constant check may be made on the progress of each flight and on the effectiveness of the time separation provided. As each new flight plan is received,

FEDERAL AVIATION AGENCY

FLIGHT PLAN

Form Approved.
Budget Bureau No. 04-R072

1 Type of Flight Plan
☐ IFR ☐ VFR ☐ DVFR

2 Aircraft Identification

3 Aircraft Type

4 Estimated True Air Speed — Knots

5 Departure Time — Proposed Z — Actual Z

6. Initial Cruising Altitude

7 Point of Departure

8 Route of Flight

9 Destination (Airport & City)

10 Altitude Changes En Route

11 Estimated Time En Route — Hours — Minutes

12. Fuel on Board — Hours — Minutes

13 Alternate Airport

14 Remarks

15. Pilot's Name

16. Pilot's Address or Aircraft Home Base

17 No. of Persons Aboard

18 Color of Aircraft

19. Flight Watch Stations (FAA use)

SEE REVERSE SIDE

CLOSE FLIGHT PLAN UPON ARRIVAL

Form FAA-398 (2-60)

AIRCRAFT IDENTIFICATION

(Reverse side)

PRE-FLIGHT PILOT CHECK LIST

WEATHER (DESTINATION) (ALTERNATE)	☐ PRESENT	
	☐ FORECAST	
WEATHER (EN ROUTE)	☐ PRESENT	
	☐ FORECAST	
	☐ PIREPS	
WINDS ALOFT	BEST CRZG ALT	
NAV AID & COMM STATUS	☐ DESTINATION	
	☐ EN ROUTE	
AIRPORT CONDITIONS	☐ DESTINATION	
	☐ ALTERNATE	
ADIZ	☐ AIRSPACE RESTRICTIONS	

REMARKS

REPORT WEATHER CONDITIONS ALOFT

Report immediately weather conditions encountered — particularly cloud tops, upper cloud layers, thunderstorms, ice, turbulence, winds and temperature.

POSITION	ALTITUDE	TIME	WEATHER CONDITIONS

Figure 18

1960 OF - 543890

Form FAA-398 (2-60)

AIRCRAFT CLEARANCE (DELIVER DUPLICATE TO BASE OPERATIONS AT DESTINATION)	DATE
A. OPERATIONS OFFICE N.A.F. ANDREWS	AIRCRAFT SERIAL NO.

B. OCCUPANTS *(State whether crew or passenger. List additional passengers on separate sheet and attach.)*

DUTY	NAME AND INITIALS	GRADE	SERVICE NO.	ORGANIZATION	HOME STATION
PILOT IN COMMAND					

C. FLIGHT PLAN

RADIO CALL	AIRCRAFT TYPE	POINT OF DEPARTURE NAF ANDREWS

ROUTE TO BE FLOWN

IFR	VFR	ALTITUDE	ROUTE	TO

BASE NAME OF DESTINATION	
MILEAGE NAUT.	ETD
EST TRUE A/S KTS.	ETE
ALTERNATE	ETE TO ALTERNATE
TRANS. FREQ.	
PILOT'S LAST NAME	
FUEL ON BOARD HRS. MIN.	

INSTRUMENT RATING

NAVY	AIR FORCE	ARMY
SPECIAL PILOT	PILOT RATING	PILOT RATING
STANDARD PILOT	INST RATING	INST RATING

DATE INSTRUMENT CARD EXPIRES	
DD FORM 365F FILED AT	DATE FILED
HIGHEST RANK ON BOARD	

LETDOWN EQUIPMENT ABOARD AIRCRAFT					LETDOWN AVAILABLE AT DESTINATION						NOTAMS CHECKED	
ILS	VOR	ADF	RADIO RANGE	TACAN	ILS	VOR	ADF	GCA	RADIO RANGE	TACAN	YES	NO

REMARKS

(SIGNATURE OF PILOT)

D. WEATHER

EXISTING			FORECAST	
DESTINATION	TIME OF OBS		DESTINATION *(ETA)*	
ALTERNATE	TIME OF OBS		ALTERNATE *(ETE)*	

ROUTE FORECAST				
MIN CIG AT	MAX CLD TOPS FT MSL	THUNDERSTORMS	TURBC	HAIL
MIN VIS FLT LVL	DUST OR HAZE	SMOKE	RAIN	FOG
MIN FRZ LVL FT MSL	ICING	FRZ PCPN	SNOW	BRIEFING VOID AFTER
WINDS			SIGNATURE	

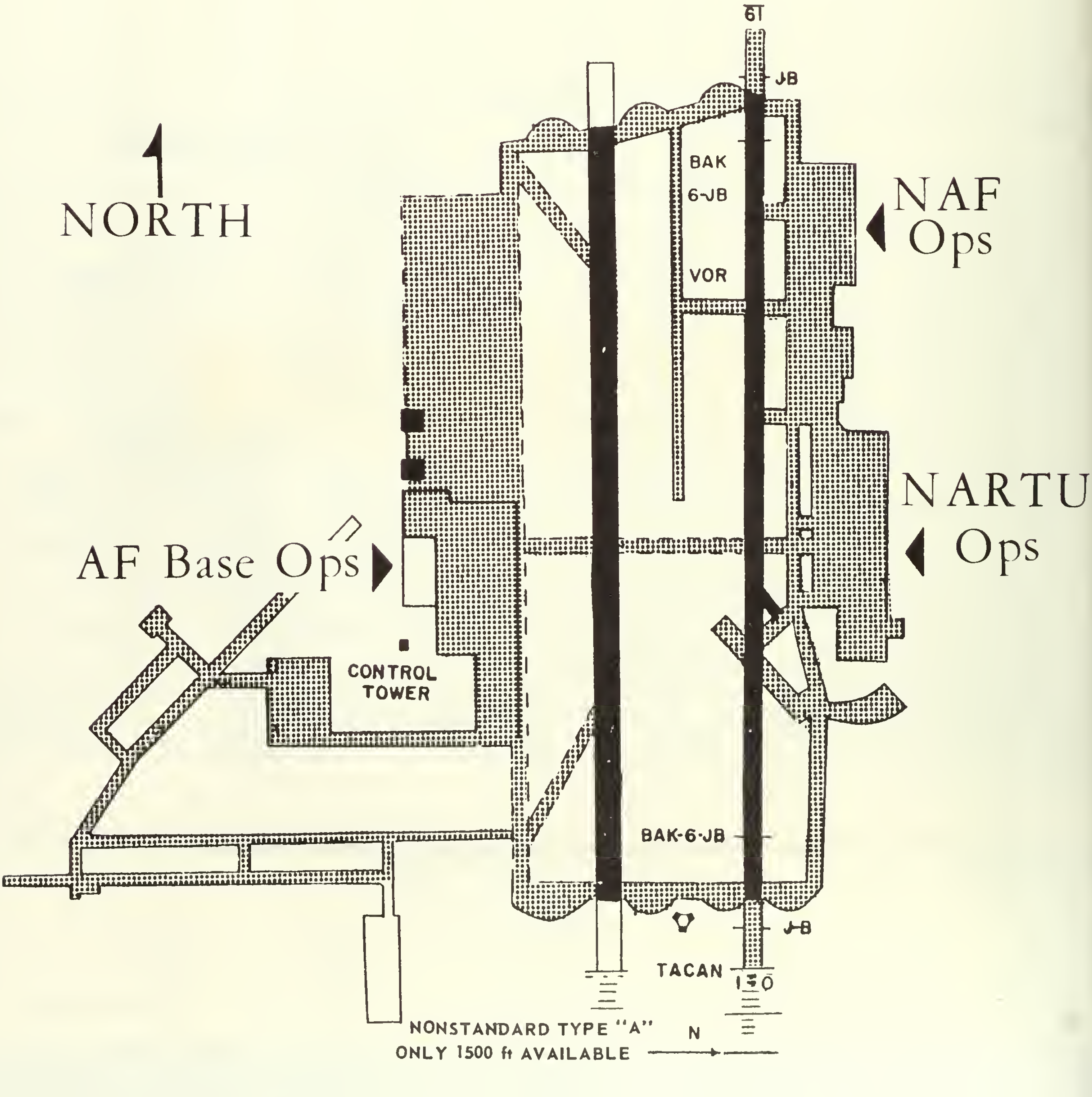
E. FLIGHT CLEARANCE AUTHORIZATION

SUBMITTED TO	TIME	BY	SIGNATURE OF CLEARING AUTHORITY
INSTRUCTIONS AND APPROVAL TRANS. TO TOWER OR PILOT BY		ACTUAL T. O. TIME	
STATION ARRIVED AT	TIME	NAME	GRADE OR POSITION

Figure 19

NAVAL AIR FACILITY
Andrews Air Force Base

Air Force Base Operations.................. 316.4 UHF
Naval Air Facility VIP LIASION 135.5 VHF
386.8 UHF



the time the aircraft will pass over each fix enroute is estimated and compared with the reported and estimated times of other flights to determine the necessary separation instructions given by the controllers. In Chapter Two, we read that FAA operates over 219,000 miles of airways with over 35 ARTCC. These centers are connected with literally tens of thousands of telephone and telegraph circuits. Information required to control air traffic pours into each ARTCC over these circuits and this information is tabulated for instance reference on flight progress boards. These boards are composed of many flight strips on which information concerning a single flight is written. At the present time, there are six ARTCC which print the flight strips using ADP -- the remainder are still being hand-written. (See Figure 20, Page 44) for a smaple of a flight strip).

As the pilot reports his progress, the flight strips are updated, analyzed and compared with the estimated progress plus comparing them with other aircraft progress. If a conflict arises between two flights, that is, if a block of air appears to be imminently in danger of intrusion, the controller will relay correcting instructions to the flights involved. When the flight has progressed far enough so that reference to data for some of the fixes is no longer required, the strips are removed and filed as permanent records.

The present system of air traffic control is a good system but it requires a great amount of attention on the part of the pilot and air controller. If the forecasted number of instrument flights are valid,

Figure 20

FAA 566X1 (7-58)	TEST12	PSK ØØØØ L188 364	Ø5 ØØ	ROA	13Ø	TYS V16 V157 DCA THIS IS A TEST
FAA 566X1 (7-58)	TEST12	ROA ØØØ5 L188 364	13 ØØ	7CF	13Ø	TYS V16 V157 DCA THIS IS A TEST
FAA 566X1 (7-58)	TEST12	7CF ØØ13 L188 373	21 ØØ	GVE	13Ø	TYS V16 V157 DCA THIS IS A TEST
FAA 566X1 (7-58)	TEST12	GVE ØØ21 L188 37Ø	29 ØØ	NYG	13Ø	TYS V16 V157 DCA THIS IS A TEST
FAA 566X1 (7-58)	TEST12	NYG ØØ29 L188 37Ø	31 ØØ	↓ 710	13Ø	TYS V16 V157 DCA THIS IS A TEST

☆U.S. GOVERNMENT PRINTING OFFICE: 1959—514225

Figure 20a

the present system will become overloaded, as happens today in periods of heavy traffic. It is not at all unusual, in periods of heavy traffic, for a controller to refuse to authorize additional flights until such time as he can get those already in the air to their destination or blended into an organized, manageable pattern. Controllers work under great pressure and mental stress is severe. Among the pilots, frustration and annoyance often results because of delays. These frustrations are mainly due to a lack of understanding of the difficulties encountered by the ARTCC. In the next section to this Chapter of How and Why ADP, the personnel problems will be briefly discussed and it will be pointed out how personnel trained in ATC <u>and</u> ADP can help to alleviate the growing problems of air traffic control.

CHAPTER III

PERSONNEL CONSIDERATIONS

The unprecedented speed and flexibility with which ADP can process a problem often results in the organization losing sight of why the installation was made. Furthermore, the increasing sophistication of the mathematical techniques used in Operations Research, Systems Analysis and the eventual programming of the ADPS cause some managers/supervisors to overlook the limitations. The most significant limitation is personnel. This includes recruiting, training/retraining, motivation, compensation and the continuing aspects of employee and public relations.

The key employee in the ADPS is the manager. Several equipment manufacturers have made studies of the requirements for such an employee. A typical comment is one made by the International Business Corporation.[11]

One of the most important considerations when installing data processing equipment is the selection and training of personnel -- here is no set of rules which can automatically guarantee that the requirements for personnel of the desired type will be met.

The most important person to be selected is the data processing manager. This selection should be made with considerable care as this individual will be responsible for the direction and leadership of all phases of the installation program --- Candidates to be considered should have the following general characteristics:

1. Be alert and inquisitive individuals.
2. Possess ability to get along with people.

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[11] International Business Machines, General Information Manual, RAMAC 305 Instruction Manual", p. 10.

3. Have ability to apply logic to the statement of a problem and its possible solutions.
4. Possess aptitude and desire for systems work.
5. Some knowledge of data processing equipment and its use is desirable though not essential.
6. Be presently in a supervisory capacity and possess comprehensive knowledge of the equipment to be installed.
7. Have past experience in methods work and knowledge of the operation of data processing equipment if possible.
8. Be capable of management presentations.
9. Have demonstrated ability in the foregoing - - .

IBM's criteria for candidate selection is somewhat overwhelming and in addition, the criteria are contradictory to a degree. On one hand, IBM stated, candidates should possess comprehensive knowledge of the equipment to be installed <u>and</u> on the other, some knowledge of data processing equipment and its use is desirable, though not essential.

FAA does not require its data processing candidates to have a comprehensive knowledge of ADP equipment. Rather, a comprehensive training program as an air controller is conducted as a prerequisite for assignment to the ADPS. All personnel working with the ADPS are qualified air controllers. Upon completion of this training period, candidates are ordered to a five week ADP school, after which a comprehensive on-the-job training program is conducted. The data processing supervision is usually the senior in grade air controller.

A minimum disruption of work will occur if substantially all of the operating personnel requirements are satisfied from within the organization. The great advantage of this technique is the stability of employment offered and this advantage should be stressed as policy in public relations and employee relation efforts incident to installation. Required training courses, such as the five-week training course for air controllers are available from equipment vendors. Once personnel have been selected, trained and working with ADP, employee motivation may be necessary to maintain the initial "bloom of expectancy."

In an interesting recent comment, Mr. W. F. Spangler, Comptroller of Owens-Illinois Glass Company said:

> "Speed of communication between activities is now the greatest stumbling block -- Station wagons with drivers between plants is sometimes the most economical method -- Teletype is not entirely adequate."[12]

The present state of the art of ADP in air traffic control requires the mundane "stuffing" of cardboard flight strips in their plastic holders by hand. This operation necessitates stripping the flight strips from the printer and individually sliding them (stuffing), into plastic holders so that air controllers can position them on flight progress boards. It doesn't require much imigination to see that top-grade personnel get bored doing this tedious task - [a task which a trained chimpanzee could probably accomplish faster and better]. Unfortunately, "station wagons" are still required in this embroyonic stage of ADP in ATC. Personnel

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[12] W. F. Spangler, Comptroller, Owens-Illinois Company, is an address to the Navy Graduate Comptrollership Program, The George Washington University, 12 December 1961.

motivation is of tremendous importance, even in this age of advanced technology.

This motivation can take many forms such as increased financial compensation, personal recognition, a realization that ADP is in its infancy and present personnel have a stake in the future, etc. Usually, personnel desiring to enter the ADP field are sufficiently motivated without additional effort. Research has disclosed that all FAA air controllers desiring to enter this field are volunteers. This fact alone, is sufficient to preclude the need at this time for a vigorous motivation effort on the part of top management. However, the "bloom of expectancy" wilts rapidly and management must be alert to recognize the symptoms.

The usual fears of job insecurity among working level personnel was not encountered among air controllers. The attitude of these people is a vital factor in the chances for success of the computer operation. Being people, they have all the ordinary fears that humans have. Fortunately, in this case, the growing workload on these people negates the fear of job insecurity. ADP can only assist them and any assistance is gratefully accepted. Computers are really gigantic arithmetic machines. Value judgments must still be made by humans. Thus as far as the air controller is concerned, the computer absorbs all the tedious, hum-drum repetitive type work and will eventually point out for the air controller, the more glamorous exceptions - air route conflicts - the unusual cases. In a word, the computer relieves the air controller of the drudgery and distills out the challenging and unique situations. In so doing, they free them from the routine details and leave time for concentration on the more important and really interesting aspects of the job.

While on the subject of personnel problems, let's turn our attention to top management. Do we really have enlightened airline presidents, FAA inspectors, military commanders, or not? Here, I'm speaking wholly in relation to the realization of the true potential offered by the complete installation of the ADPS in air control. Research to date indicates that a rather negative approach is followed by the "old line" top management. This approach is evidenced by the fact that there are at present, only six ADP installations at ARTCC. It cannot be denied that these six are successful. However, economic gain and other benefits realized to date can generally be classified as marginal. This is not bad; and it is conceded, that it is a natural and wholly expected situation. After all, ADP is really in the pioneering stages -- we are only engaged in chopping down the trees and clearing the land. The real point is, that if ADP in ATC is going to be truly successful, in all aspects, then those in position of authority must recognize its potential and begin "sowing the seed." What is really required is the harnessing of the fantastic speeds of the computer to new methods of air traffic control -- possibly operations research may find a way. The effort will be well-worth the expenditures.

CHAPTER IV

The Future

--- An adequately funded, prudently managed, continually updated research and development program of breadth and imagination is essential to the maintenance of U. S. world leadership in aviation --- .[13]

If the air traffic control system is to keep abreast of the increasing complexities of air traffic, research and development into new methods of ATC must be continually advanced. Project Beacon, Report of the Task Force on Air Traffic Control, October 1961, stated that the current FAA Research and Development budget of $65 million per year will be adequate to complement the major features of a substantially improved air control system. This system includes, among others, the following recommendations:

1. The combined SAGE/FAA radar network should be employed for enroute control and along with flight plans, provide the basic control information.

2. Altitude information should be obtained through use of altitude reporting beacon transponders carried in the aircraft. Task Force studies indicated that a short-range beacon satisfactory for terminal area use should be obtainable for no more than $500. When such a beacon becomes available, it should be required in all aircraft landing at controlled airports within designated congested terminal areas.

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[13] FAA, Project Horizon, National Aviation Goals, September 1961. p. 207, U. S. Government Printing Office.

3. General purpose ADP should be employed in both the enroute and terminal area portions of the system to process flight plans, issue clearances, make conflict probes, generate display information, establish landing sequences and perform other routine tasks of assistance to the control function.

The report stated that with complete, position information available on the ground, pilot reports should be reduced drastically and controller, pilot load and radio frequency usage therefore held to reasonable levels.

Complete radar coverage of all airborne aircraft could be one of the major aspects to the ADPS. As was mentioned, prior to the use of radar in ARTCC, the only surveillance was through pilot position reporting. The use of radar in ARTCC, by microwave relay from the relay site, has been of great assistance to the air controller. With the addition of the altitude beacon as proposed by Project Beacon, there will be even more data available for air control. With continuous flight path and altitude information being fed into the computers, it will be possible to determine probable conflicts, discuss separation standards and obtain greater traffic flow <u>with</u> improved safety.

There are several plans being considered for use of SAGE radar and computer equipments in ATC.[14] However, the Task Force on ATC, as reported in Project Beacon, found general agreement that any use of SAGE

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[14] Project Satin, Joint FAA and USAF Project. FAA/USAF, 1961.

for ATC should be considered interim and that a new system would be required by 1970. In view of this finding, the capital expense to modify SAGE for use in ATC does not appear justified, particularly in view of the large penalty in operating cost which would result in the latter years of its useful life.

The value of radar coverage has been proven. The solution to providing complete coverage of airborne traffic has yet to be found. Increasing differences in speeds and operational characteristics of modern aircraft and the greatly increasing traffic volume have established a requirement for positive separation of all aircraft, regardless of weather conditions. The present air traffic control system cannot satisfy this requirement because of its limited capabilities.

Automatic data processing can assist in satisfying this requirement. The type of control desired can take many forms. Should air control be "tight" or "loose"? Should the pilot be directed to maintain specific airspeeds? Should the flight path, that is, "profile" be stipulated to the pilot, etc. An analysis of the various types of control must be comprehensive. This analysis can be conducted by various computer techniques. The "Finite Difference" approach[15] has been developed. This approach answers the question "What type of control will minimize the amount of fuel used by aircraft in landing at a terminal under crowded conditions?" The use of ADP helps answer these questions relatively inexpensively since the proposed system can be analyzed prior to the expenditure of funds for building the system.

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[15] Korn, Karl E., "Analytical Testing in Air Traffic Control Systems," Computers and Automation, August 1961, p. 15.

As systems get larger and more complex, the job of analyzing them gets increasingly difficult. A satisfactory analysis usually requires a mathhmatical model which is far beyond the means of the unaided human calculator. In such cases, only the use of high speed digital computers makes an analysis possible.

In another Article,[16] Mr. Kugel points out that there may be more than one approach to presenting a mathematical model for analyzing the ATC systems -- there are many.

Thinking in terms of what has been done, where we are and where we will probably be in the near future, we can vizualize that the computerization of various ATC functions will expand to include all the mechanical functions now performed by hand. Value judgments, such as conflict resolution, will remain the perogative of the air controller, as assisted by ADP. One can visualize the computer issuing a warning by audio and/or visual means when the block of airspace allocated to one aircraft is being intruded by another aircraft. Computer logic will immediately offer alternative routes or altitudes to the air controller for his assistance. The air controller, then determines the best alternative for the aircraft involved in the impending conflict, and transmits the alternative to the appropriate aircraft.

One company presently working on developing revolutionary air traffic procedures for the future is the System Development Corporation.[17]

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16 Kugel, Peter, "Mathematical Models of Air Traffic Control Systems," Computers and Automation, November 1961, 10.

17 System Development Corporation, Santa Monica, California, U. S. News and World Report, 2 April 1962, p. 30.

Simulation techniques are used extensively to determine the most effective "mix" of man and machine in order to direct the air traffic of the future.

Operations research, systems analysis and management engineering will continue to play an important role in developing new systems of ATC. The area of operations research appears to have the greatest potential. The goal of the future is the best possible method of safely controlling air traffic with the least expenditure of resources.

CONCLUSIONS

Air traffic control must be improved, expanded, supplemented and reinforced to cope with expanding instrument flying. Due to the increasing differences in speed and operational characteristics of aircraft, there is a requirement for the positive separation of all airborne traffic. The present air traffic control system cannot satisfy this requirement.

ADP can assist the air controller in his ever-demanding job of directing traffic.

ADP is a tool which, like all tools, must be appraised for proper use and application. Ill used, it results in pyramiding costs to the detriment of further application. Properly used, it provides an effective product which generates enthusiasm, motivates further research and promotes increased safety. It is not a replacement for air controller decisions, rather, it is an adjunct to far more effective ATC.

Knowledge of the potential and the weaknesses of ADP is essential to the top manager. The impact of this equipment on people, the organization and the syssem itself is no less than the impact of any other mechanization. This mechanization requires discrete, planned, and organized effort to turn to the advantage of the potential users. To select ADP by ill-advised miscalculations is to invite misfortune. By the same token, the use of such equipment requires continuing management effort to increase operating efficiency, to fully profit by the personnel advantages possible, to derive accelerated air controller decisions and to optimize safety of air travel.

The future of ADP will be more of the past, rapid technological evolution, accelerated application and the discovery of new techniques. The need is to know ADP, to apply it and to use it for the betterment of all users of the crowded sky.

GLOSSARY OF AIR TRAFFIC CONTROL TERMS*

ACFT - Aircraft; any contrivance used or designed for flight in the air.

ADF - Automatic Direction Finder.

Aerology - That part of meteorology that deals with the study of upper air regions.

AGCA - Automatic ground control approach (See also GCA).

Airport Surveillance Radar (ASR), relatively short range radar used primarily by approach control personnel for arrival and departure control of aircraft within about a 50 mile area.

Airport Traffic Control - A service provided by airport management to provide supervision of air traffic within the airport area.

Air Route Surveillance Radar (ARSR), long range radar (about 150 miles), used by ATC personnel to control air traffic.

Alternate airport - An airport to which a flight may proceed if landing not accomplished at point of first intended landing.

Altimeter - A device which measures altitude of aircraft may be aneroid, radio, radar, etc.

AOPA - Aircraft Owner's and Pilot's Association.

Approach Control - Air traffic control service established to control arriving and/or departing IFR flights.

Approach Sequence - Landing sequence established by approach control.

Approach time - The time at which an aircraft is expected to commence its approach to the airport.

ARTC(C) - Air Route Traffic Control (Center), a facility established by FAA to provide air traffic control service.

ASAP - As soon as possible.

ATC - Air Traffic Control; a service operated by appropriate authority to promote safe, orderly and expeditious flow of air traffic.

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* For a detailed glossary of Air Traffic Control Terms, see Plane Talk, second edition, May 1961, prepared by the Presentations and Air Traffic Programs Groups of The Martin Company

Beacon - transmitter or transceiver for use as a marker device.

CAA - Civil Aeronautics Administration, a division of the Department of Commerce until 1958, has been superseded by and incorporated into the FAA.

CAB - Civil Aeronautics Board, a five man federal agency with members appointed by the President, charged with responsibilities for regulating the economies of the aircraft industry.

CAR - Civil Air Regulations, as prescribed by FAA.

CAVU - Ceiling and visibility unlimited.

Ceiling - The vertical distance between the ground or water, and the lowest layer of clouds that is reported as "broken", "overcast" or "observation".

Clearance - An ATC authorization to proceed per traffic conditions within airspace controlled by ARTCC.

Control Area - Defined airspace, extending up from 700 feet MSL above surface, within which ATC is exercised.

Control Zone - Defined airspace, extending from the surface upwards, within which rules additional to those governing flight in control areas apply for protection of air traffic.

Cross wind - A wind which blows across the path of an aircraft.

Data link - A communication channel used for transmitting data.

DECCA - A long range electronic navigational aid to aircraft.

DME - Distant measuring equipment; a term denoting a means of measuring distances.

DOD - Department of Defense.

ETA - Estimated Time of arrival.

ETE - Estimated Time enroute.

ETD - Estimated Time of departure.

FAA - The Federal Aviation Agency. (See CAA)

Fix - The position in space of a moving craft at a specific time.

Flight plan - Specified information filed either verbally or in writing with ARTCC, relative to the intended flight of the aircraft.

FIM - Flight information manual,issued by FAA.

Flight Progress Strip - A strip of paper which contains information necessary for aircraft control purposes.

Flight Visibility - The horizontal distance that prominent objects may be seen from the cockpit.

Flow Control - Limitation applied to the flow of air traffic to keep elements of the common system, such as airports or airways, from becoming overloaded.

Head Wind - A wind which blows approximately parallel to the line of flight of an aircraft and which reduces the ground speed of the aircraft.

High Density airport - An airport so designated by the FAA Administrator upon his finding that traffic in its vicinity has reached such a high volume that special rules are necessary in the interest of safety.

Holding point - A specific location, identified by visual or other means, in the vicinity of which the position of the aircraft in flight is maintained in accordance with air traffice control instructions.

Hypersonic - Pertaining to speeds in excess of MACH 5.

IFF - Identification Friend or Foe; a method of electronic interrogation of aircraft used in conjunction with radar for identification of friendly aircraft.

IFR - Instrument Flight Rules

ILS - Instrument Landing System - received electronic signals operate instruments in the cockpit to alert the pilot of any deviation from the ideal safe approach -- these signals may be coupled with an automatic pilot for a completely automatic approach.

Jet Routes - Routes delineated in the continental control area at and above specified altitudes established by the FAA Administrator.

Lateral Separation - Lateral spacing of aircraft at the same altitude by specifying different routes or geographical locations per aircraft.

Longitudinal Separation - Longitudinal spacing of aircraft at the same altitude by minimum space distance.

Mach Number - A term commonly used to state the speed of a supersonic craft or missile (e.g., Mach 1 -- speed of sound).

MEA - Minimum Enroute Altitude.

Military Climb Corridor - A restricted area under positive control, in the vicinity of a military intercepter airport.

Movement Areas - That part of an airport reserved for the taking-off, landing and taxiing of aircraft.

NOTAM - Notice to airmen; a notice concerning the status of equipment and safety of flight items.

Outer Fix - A fix in the terminal area used to position aircraft for proper approach configuration.

PAR - Precision Approach Radar; the precision radar set of the ground controlled approach (GCA) system.

Peripheral Communications - Location of air/ground communications system to provide coverage to the periphery of a controlled area; direct link from pilot to controller.

Positive Control - A service provided by ATC in controlled airspace wherein ATC provides positive aircraft separation in all weather.

Prohibited area - Airspace over an area within which aircraft flight is prohibited.

RAPCON - Radar Approach Control Center; USAF radar equipment used for approach control at military air bases.

RATCC - Radar Air Traffic Control Center; a U.S. Navy radar installation used for approach control at Naval Air Stations.

Reporting Point - a geographic location in relation to which the position of an aircraft is reported or is to be reported.

Restricted area - Airspace over an area wherein a hazard to flight or navigation exists.

Separation Standards - The minimum longitudinal, vertical or lateral separation provided aircraft by ATC.

SOP - Standard Operating Procedure.

STOL - Short Takeoff and Land -- applied to an aircraft which is similar to UTOL, but unable to hover.

Subsonic - Pertaining to speeds less than the speed of sound.

Supersonic - Pertaining to speeds in excess of the speed of sound, but less than MACH 5. (See hypersonic)

Take-off Clearance - Authorization by an airport traffic control tower for an aircraft to takeoff.

Traffic pattern - Flow of aircraft on and in the vicinity of an airport during specific weather established by appropriate authority.

Vectoring - Controlling the flight of aircraft by issuance of a sequence of instructions giving directional changes needed for desired path.

VFR - Visual flight rules; in general, navigation by visual sighting of landmarks and collision avoidance on a "see and be seen" basis.

VOR - Very High Frequency Ornnidirectional Radio Range.

VORTAC - A short range navigation facility that provides pilots of equipped aircraft with information on bearing and distance to or from the VORTAC ground station.

Warning Area - An airspace with the same flight restrictions as a restricted area but located outside the territorial limits of the United States.

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